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By:____________________ Date: September 16, 2003

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant	:	Ulrich Baier
Appl. No.	:	10/647,614
Filed	:	August 25, 2003
Title	:	Method for Etching a Hard Mask Layer and a Metal Layer

CLAIM FOR PRIORITY

Hon. Commissioner for Patents,
Alexandria, VA 22313-1450
Sir:

Claim is hereby made for a right of priority under Title 35, U.S. Code, Section 119, based upon the European Patent Application 01 1043 59.3 filed February 23, 2001.

A certified copy of the above-mentioned foreign patent application is being submitted herewith.

Respectfully submitted,

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Bescheinigung

Certificate

Attestation

Die angehefteten Unterlagen stimmen mit der ursprünglich eingereichten Fassung der auf dem nächsten Blatt bezeichneten europäischen Patentanmeldung überein.

The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

Patentanmeldung Nr. **Patent application No.** **Demande de brevet n°**

01104359.3

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
p.o.

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Blatt 2 der Bescheinigung
Sheet 2 of the certificate
Page 2 de l'attestation

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Anmelder:
Applicant(s):
Demandeur(s):
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Title of the invention:
Titre de l'invention:
Method for etching a hardmask layer and a metal layer

In Anspruch genommene Prioriät(en) / Priority(ies) claimed / Priorité(s) revendiquée(s)

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THE APPLICATION WAS TRANSFERRED FROM THE ORIGINAL APPLICANT:
- SEMICONDUCTOR 300 GMBH & CO KG in DRESDEN (DEUTSCHLAND)
TO THE ABOVE MENTIONNED APPLICANT ON:
- 28.02.2002

Description

Method for Etching a Hardmask Layer and a Metal Layer

The present invention relates to an insitu hardmask open strategy which is performed before carrying out a metal etch. The present invention is particularly suited for the processing of 300 mm silicon wafers.

Plasma assisted dry etching processes are widely used in the field of microelectronics and micromechanics. When features having a high aspect ratio are to be patterned as well as when rather etch resistant layers have to be patterned, very high demands must be met by the etching mask. In most cases photoresist masks are unsufficient in order to achieve the necessary etching selectivities. In these cases so called hard masks are used, the patterning of which again can become a severe problem.

Figure 1 illustrates an exemplary layer stack which is to be patterned by plasma etching. On a SiO_2 base layer 4 which is usually provided on a semiconductor wafer, especially a silicon wafer, 10 nm of Ti, 400 nm of an alloy comprising 99,5 % Al and 0,5 % Cu, 5 nm of Ti and 40 nm of TiN are deposited as a metall layer stack 3. Trenches having a width of approximately 140 nm are to be etched into the metal layer stack 3. In order to selectively etch these trenches, first, 180 nm of a SiON layer 2 are deposited as a hardmask material, followed by 490 nm of a generally used photoresist material 1. First, as is shown in Figure 4, the pattern is photolithographically defined into the photoresist layer 1, then the SiON layer 2 is etched in a plasma etching process, and finally, the metal layer stack 3 is etched in another plasma etching process.

It has been rendered to be very advantageous if the hardmask layer, which is for example made of SiON, and the metal stack are etched insitu, which means that hardmask and metal stack

are etched in one single plasma processing chamber. In particular, when the hardmask and the metal stack are etched insitu, no additional plasma processing chamber and no additional wet clean chamber are necessary. Additionally, it is not necessary to move the silicon wafer from one plasma processing chamber to another thus reducing the processing time and cost.

As an etchant for etching the hardmask layer, usually a mixture of a fluorine containing gas such as CF_4 or CHF_3 and Cl_2 is used. As an etchant for etching the metal layer stack, conventionally a mixture of a chlorine containing gas such as BCl_3, Cl_2 and, optionally, N_2 and CHF_3 is used.

As becomes apparent from Figure 4, a problem arises since the hardmask layer 2 is not vertically etched but assumes a tapered profile. As a consequence, as can be seen from Figure 5, after the metal layer stack etching step, the bottom of the trenches will have a much smaller width than the top of the trenches. Accordingly, when the metal etch is performed in order to define interconnection wirings, for example, the width thereof will be greater than that was lithographically defined in the photoresist layer. Generally speaking, the width denoted by reference numeral 5 in Figure 4 is generally referred to as the "CD" or "critical dimension".

It is an object of the present invention to achieve a better control of the CD. Especially it is an object to reduce the CD in an insitu hardmask open step.

According to the present invention, the above object is achieved by a method for etching a hardmask layer made of SiO_2 (silicon oxide), Si_3N_4 (silicon nitride) or SiON (silicon oxynitride), the method comprising the steps of providing a substrate having thereon at least one metal layer, a hardmask layer made of SiO_2, Si_3N_4 or SiON and a patterned photoresist mask overlying said hardmask layer in a plasma processing

chamber, etching said hardmask layer in a plasma etching process using an etchant source gas which comprises a fluorine containing gas and oxygen, etching the at least one metal layer in the same plasma processing chamber after the hardmask layer has been etched.

As the inventors of the present invention found, in an insitu hardmask open process the CD of metal lines can be advantageously reduced if a small amount of oxygen is added to the etchant source gas used for etching the hardmask.

In particular, it was found that the metal etch step provides almost perpendicular walls whereas the taper is mainly induced by the hardmask opening step. More specifically, when performing any anisotropic plasma etching process, the etchant source gas will also attack the photoresist layer whereby polymers will be produced which will then be deposited at the sidewalls of the trench. For example, during the metal etch step, a thin polymeric film will be formed on the trench walls so as to prevent the walls from being further etched, whereas the thin polymeric layer deposited on the trench bottom will be destroyed by ion bombardment during the plasma etching process. In contrast, due to the specific plasma conditions during the hardmask open step, the polymeric layer will be deposited onto the trench walls so as to produce a tapered shape.

By adding a small amount of oxygen, for example 5 to 10 sccm (cubic centimeters per minute under standard conditions) if 100 sccm of a fluorine containing gas are fed, this tapered shape can be avoided, whereby a vertical etching profile is achieved. Consequently, the CD can be better controlled and further be reduced.

Moreover, the present invention provides a method for patterning a metal layer stack comprising at least one metal layer on a substrate, comprising the steps of the method according

as defined above, and the step of etching said at least one metal layer in said plasma processing chamber in another subsequent plasma etching process. Both etching processes are performed within the same plasma processing chamber preferably without breaking the vacuum.

A problem which may arise when the insitu etching process for etching the hardmask layer and the metal stack including a layer containing aluminium is performed a plurality of times so as to process several wafers is that the aluminium etched will be deposited on the plasma processing chamber walls. If thereafter a new wafer is introduced into the plasma processing chamber and a hardmask etching step using oxygen is performed, the deposited aluminium will react with the oxygen to form aluminium oxide which is very brittle and, thus, will peel off the plasma processing chamber walls so as to fall onto the wafer and cause unwanted impurities on the wafer surface.

This problem can be solved if the plasma processing chamber is cleaned by an additional plasma cleaning step using for example an inert gas or oxygen as a cleaning gas, the cleaning step being performed after the metal etch step.

Using this plasma cleaning step, all the polymers and all the aluminium which have been deposited on the plasma processing chamber walls during the metal etch step will be removed before the next oxygen containing hard mask open step of the next wafer will start.

In summary, the present invention provides the following advantages:

- The hardmask layer and the metal stack are etched insitu, that is in one single plasma processing chamber and without breaking the vacuum lock. Accordingly, only one plasma etching tool and only one wet cleaning device are necessary.

Consequently, processing cost can be reduced. Moreover, since the vacuum is maintained and the wafer need not be transferred from one plasma processing chamber to another, the processing time can be considerably reduced.

- The tapered etching profile in the hardmask layer is avoided. Thus, vertical walls can be etched in the hardmask layer and the metal layer stack, whereby the CD can be remarkably reduced and be better controlled. In particular, the CD defined in the photoresist layer corresponds to the CD etched into the metal layer stack.

Figure 1 shows a metal layer stack having a hardmask layer and a patterned photoresist layer thereon, the metal layer stack being deposited on a SiO_2 base layer;
Figure 2 shows the metal layer stack of Figure 1 after performing the hardmask open step of the present invention;
Figure 3 shows the metal layer stack of Figure 2 after selectively etching the metal layer stack;
Figure 4 shows the metal layer stack of Figure 1 after performing the hardmask open step according to the method of the prior art;
Figure 5 shows the metal layer stack of Figure 4 after selectively etching the metal layer stack; and
Figure 6 shows an exemplary plasma processing chamber.

In Figure 1, on a SiO_2 (silicon oxide) base layer 4 which is usually provided on a semiconductor wafer, a metal layer stack 3 comprising 10 nm of Ti (titanium), 400 nm of an alloy comprising 99,5 % Al (aluminium) and 0,5 % Cu (copper), 5 nm of Ti and 40 nm of TiN (titanium nitride) are deposited. Trenches having a width of approximately 140 nm are to be etched into the metal layer stack 3. The CD 5 also is 140 nm. In order to selectively etch these trenches, first, a layer 2 of 180 nm of SiON (silicon oxynitride) are deposited as a

hardmask material, followed by 490 nm of a generally used photoresist material 1.

According to the present invention, the hardmask opening step and the metal etching step are performed in a single plasma processing chamber in two different steps using different etchants. Accordingly, the two steps are performed subsequently without breaking vacuum lock.

The plasma processing apparatus that can be used for carrying out the present invention may be any known plasma processing apparatus such as devices for dry etching, plasma etching, reactive ion etching or electron cyclotron resonance etching.

For example, the process of the present invention may be performed in a transmission coupled plasma etching apparatus (TCP) which is shown in Figure 6. In such an etching apparatus the energy for sustaining the plasma is inductively coupled to the reactor. However, in a different plasma etching apparatus, this energy could be also capacitively coupled.

The plasma processing system in Figure 6 includes a plasma processing chamber 6 having a gas inlet 9 for feeding the etchant source gas. In the present example, this gas inlet 9 is implemented as a gas dispensing apparatus having a shower head configuration. However, the gas inlet can be implemented in any other suitable manner. Moreover, there is provided a top electrode 7 which takes the form of a coil. The coil electrode 7 is energized by a RF (radio frequency) generator 8 via a matching network (not shown) as is conventional. The wafer 11 is introduced into the plasma processing chamber 6 and disposed on an electrostatic chuck 13 which acts as an electrode and is preferably biased by a RF generator 10. However, the chuck 13 may also be implemented in a different manner being connected to the RF generator 10. Helium cooling gas may be introduced under pressure through port 12 between chuck 13 and wafer 11 so as to act as a heat transfer medium

for accurately controlling the temperature of the wafer during processing to ensure uniform and reproducible etching results. In the present example, a wafer temperature of 35°C is maintained.

The RF generators 8, 10 through coil electrode 7 and chuck 13 are used to generate a plasma in the etchant source gas within the plasma processing chamber 6 in order to etch the wafer 11.

The by-product gases formed during the plasma etching process are exhausted by an exhaust line 14 which is connected with a suitable pump for maintaining the desired vacuum conditions. Typically, the chamber walls are grounded.

After introducing the wafer 11 into the plasma processing chamber 6, various stabilisation steps as generally known in the art are performed, in which the etchant source gases are fed into the plasma processing chamber without plasma so as to provide stable process conditions and to set the pressure as well as the desired gas flow rates. Thereafter, the plasma is ignited, a bias is applied to the chuck and then, a hard-mask open step is performed.

As an etchant source gas, according to the present invention, a mixture of a fluorine containing gas such as CF_4 (Tetrafluoromethane) or CHF_3 (Trifluoromethane), Argon and a small amount (approximately 5 to 20 % based on the flow rate of the fluorine containing gas) of oxygen is used. In particular, typical flow rates to be employed are 100 sccm of CF_4, 150 sccm of Argon and 5 to 20 sccm of O_2 (oxygen). The pressure prevailing in the plasma processing chamber is in the order of 1 to 1,5 Pa. The RF power applied to the top electrode 7 is set to approximately 600 to 1000 W, and the RF power applied to the chuck 13 is set to approximately 150 to 300 W which are preferred settings for transformer coupled plasma (TCP) tools. The radio frequency employed is 13.56 MHz.

As the inventors of the present invention found out, the addition of Argon to the echant source gas additionally decreases the CD, since reaction products are carried off more quickly. This is also the case if an etchant source gas of a fluorine containing gas without oxygen is used. In particular, a flow rate of Argon which is greater than that of the fluorine containing gas, for example a ratio of 1,5 between Argon gas flow rate and fluorine containing gas flow rate, has provided excellent results.

After the hardmask opening step, various gas rinsing steps can be performed, in which inert gases such as Argon or N_2 (nitrogen) are fed so as to remove residual gases from the former etching process from the plasma processing chamber. Moreover, or alternatively, stabilisation steps as described above can be performed.

If necessary, breakthrough steps are also performed, in which the oxidized surface of a metal layer to be etched is removed by an anisotropic etching step.

Thereafter, another plasma etching process is performed so as to etch the metal layer stack. The term „another plasma etching process" means that an etchant source gas which is different from the etchant source gas used for etching the hardmask layer is used. For etching the metal layer stack, a chlorine containing gas mixture such as BCl_3 (boron trichloride) and Cl_2 (chlorine) and, optionally, N_2 and CHF_3 is used as an etchant source gas.

Moreover, various overetch steps as generally known in the art are performed.

After that, the wafer 11 is removed from the plasma processing chamber and, then, optionally, after introducing a dummy wafer for protecting the chuck, a plasma cleaning step using

oxygen or an inert gas such as N_2 can be performed so as to clean the walls of the plasma processing chamber 6. Alternatively, the processed wafer 11 can also be removed after plasma cleaning the processing chamber 6.

The wafer 11 is then transferred to a resist-strip chamber, wherein the remaining photoresist 1 is stripped. Thereafter, the wafer is processed in a conventional manner.

After the plasma cleaning step, which can as well be omitted, the next wafer 11 to be processed can be introduced into the plasma processing chamber 6.

Claims

1. A method for etching a hardmask layer (2) made of silicon oxide, silicon nitride or silicon oxynitride and at least one metal layer (3), the method comprising the steps of:
- providing a substrate (11) having thereon at least one metal layer (3), a hardmask layer (2) made of silicon oxide, silicon nitride or silicon oxynitride and at least one metal layer (3) and a patterned photoresist layer (1) overlying said hardmask layer (2) in a plasma processing chamber (6);
- etching said hardmask layer (2) in a plasma etching process using an etchant source gas which comprises a fluorine containing gas and oxygen,
- etching the at least one metal layer (3) in the same plasma processing chamber (6) after the hardmask layer (2) has been etched.

2. The method according to claim 1, wherein the flourine containing gas is CF_4 or CHF_3.

3. The method according to claim 1 or 2, wherein the etchant source gas additionally comprises Argon.

4. The method according to any of the preceding claims, wherein the flow rate of oxygen is 5 to 10 % based on the flow rate of fluorine containing gas.

5. The method according to any of claims 1 to 4, wherein the step of etching said at least one metal layer in said plasma processing chamber (6) is performed in another subsequent plasma etching process.

6. The method according to claim 5, wherein the plasma processing chamber (6) is cleaned by plasma cleaning step which is performed after the substrate (11) has been etched.

7. The method according to claim 6, wherein the plasma cleaning step is performed using an inert gas or oxygen as a cleaning gas.

8. The method according to claim 6 or 7, wherein the plasma cleaning step is performed after the metal layer (3) has been etched.

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EPO - Munich
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23. Feb. 2001

Abstract

Method for Etching a Hardmask Layer and a Metal Layer

The present invention relates to an improved insitu hardmask open strategy which is performed before carrying out a metal etch. The method for opening the hardmask (2) made of SiO_2, Si_3N_4 or SiON comprises the steps of providing a substrate having thereon at least one metal layer (3), a hardmask layer made of SiO_2, Si_3N_4 or SiON and a patterned photoresist layer overlying said hardmask layer (2), etching said hardmask layer (2) in a plasma etching process using an etchant source gas which comprises a fluorine containing gas and oxygen, wherein the plasma processing chamber used for etching the hardmask layer (2) is the same as the plasma processing chamber in which the at least one metal layer (3) is etched in another plasma etching process after the hardmask layer (2) has been etched.

Figure 3

1 photoresist layer
2 SiON layer
3 metal stack
4 SiO_2 base layer
5 critical dimension
6 plasma processing chamber
7 top electrode
8 RF generator for top electrode
9 gas inlet
10 RF generator for chuck
11 wafer
12 port
13 chuck
14 exhaust line

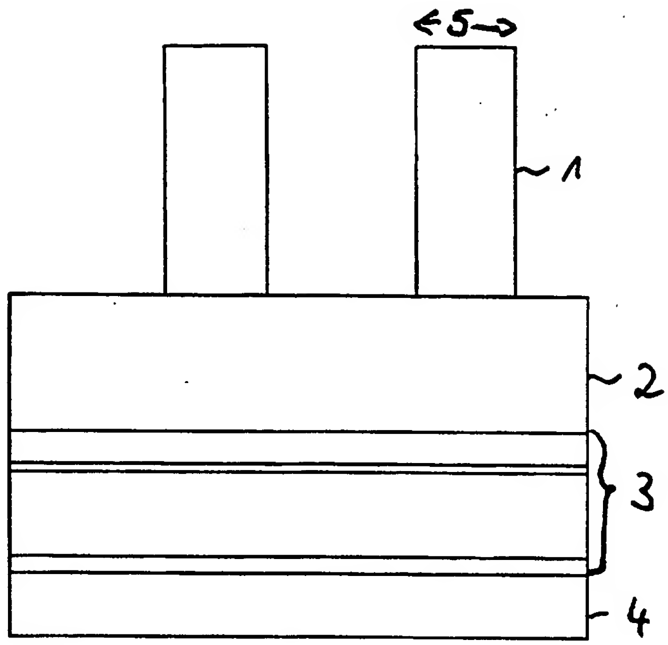

FIG.1

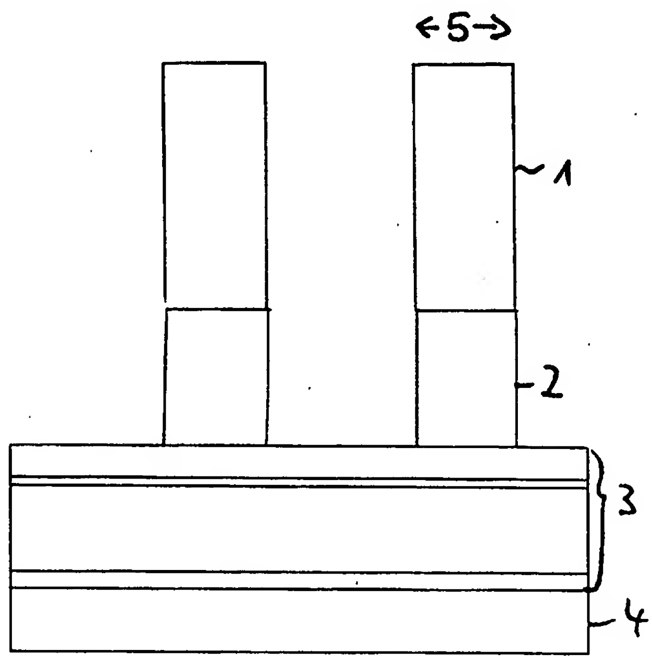

FIG.2

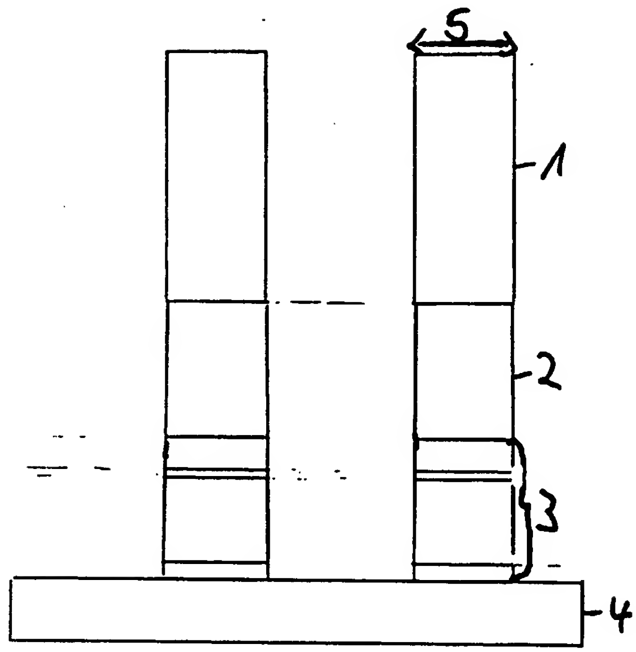

FIG. 3

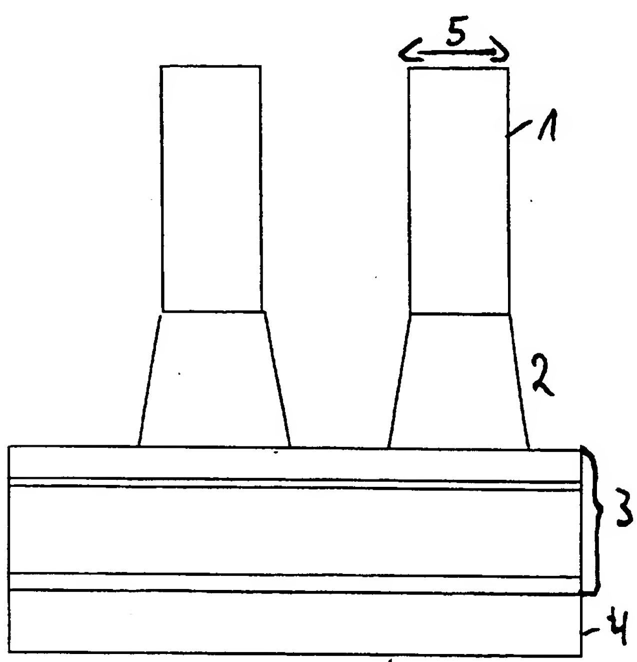

FIG. 4

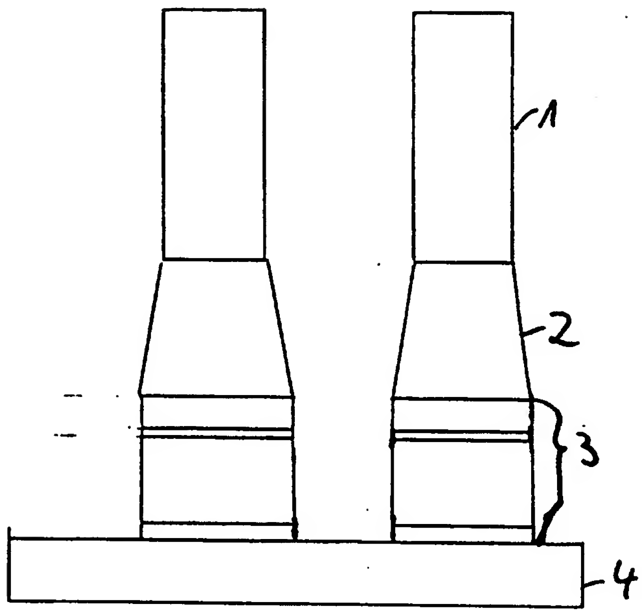

FIG.5

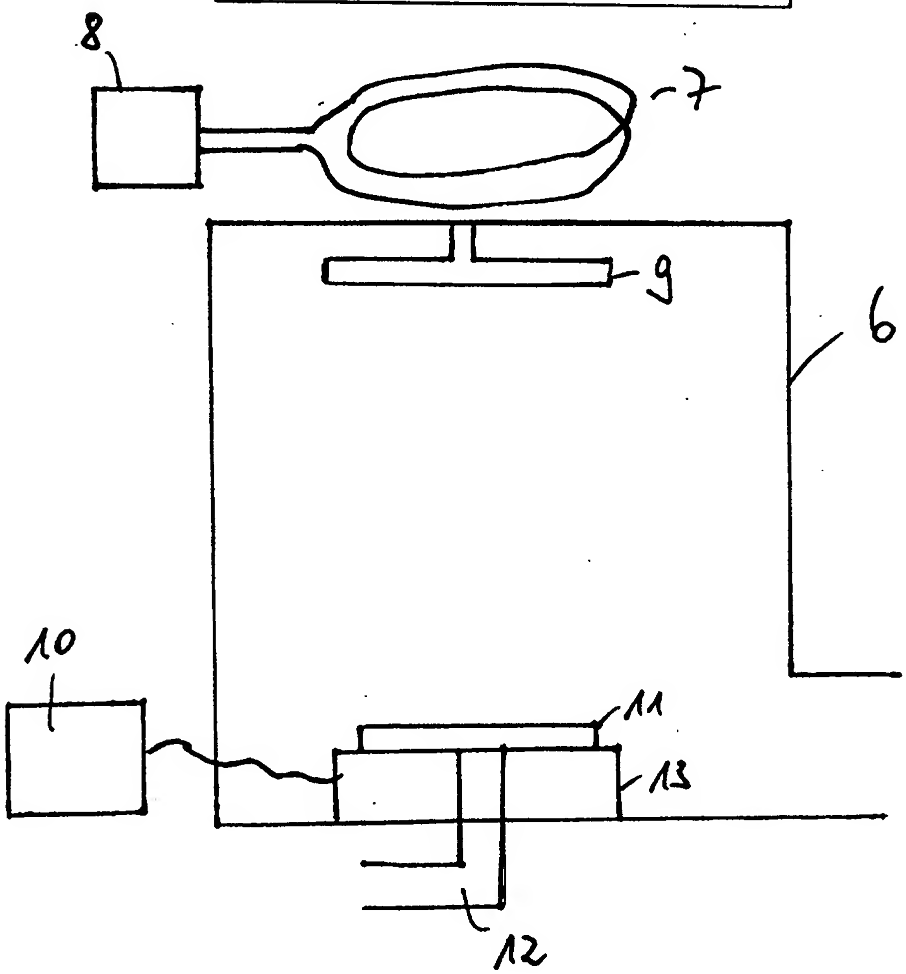

FIG.6

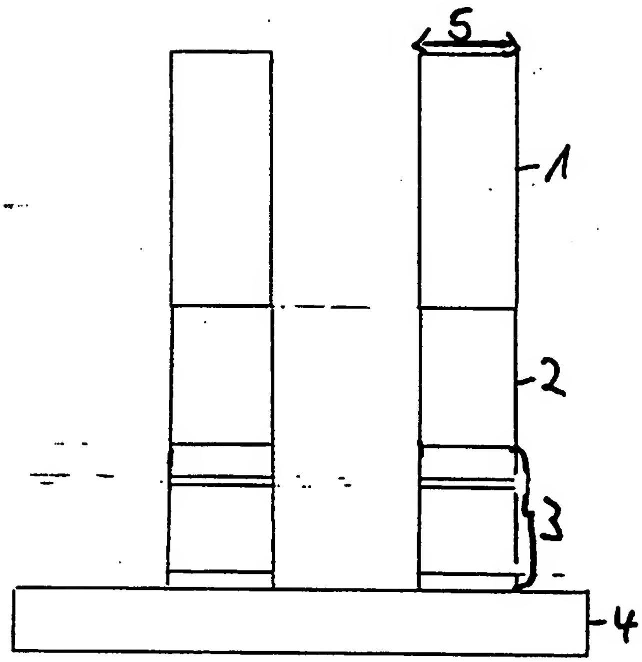

FIG. 3